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Scenarios for adaptation and mitigation in urban Africa under 1.5 °C global warming

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Cities are considered to be at the frontline of the global climate change response, both from mitigation and adaptation perspectives. But many cities are engulfed in infrastructure deficits, carbon intensive development while urban poverty adds to this complexity in Africa. Africa's rapid urbanisation is coming with opportunities and challenges but the contribution of this urbanization to limit global warming at 1.5 degrees requires new knowledge on the interactions between adaptation and mitigation. Climate impacts on African cities are growing, with spatially differentiated warming of between 0.3 and 0.7 degrees. Rainfall redistribution and excessive rainstorms have impacted African cities in various ways. Many of the African cities are, however responding to the challenges through the formulation of adaptation plans, mitigation strategies with a strong focus on resilience and sustainable development — as outlined in the African Union's Agenda 2063. Given that most cities in Africa are low emitting cities, this paper discusses how adaptation and mitigation can be coupled using three scenarios in the context of 1.5-degree warming. It is also recognized that the different ecologies of Africa offer multiple possible pathways of adaptation and mitigation for increased African urban resilience.

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Introduction

African cities are undergoing spatial, social, economic and environmental transitions in addition to leading the urbanizing globally [1,2]. This is due to multiple drivers of technology-driven development, global capital transfers, demographic transitions and increasing environmental change affecting African primary rural production activities [3•]. Many cities in Africa have grown spontaneously, with a mix of ultra modern developments, informal settlements and agricultural activities. Global Capital movement to Africa in form of Foreign Direct Investments and remittances from Africans in the diaspora, are also changing the consumption patterns in African cities [4•]. This results into configuration of spatial form, structure and functions of the urban areas but also exposure to climate risks. There are two broad urban development trends; the first is high-density developments as the case of Lagos, Kinshasha, Nairobi, Johannesburg and the second of spatially expanding cities such as Dakar, Kampala, Addis Ababa and Dar es Salam [5]. Both trends map on to colonial cities but display many differences in the nature of development described as African urbanism [6,7••]. Africa is described as leading the 'second wave' of urbanization [8••] that is characterized by growth in urban population that is hypothesized not to march the economic growth [9]. The second urbanization wave is characterized by informality that is widely documented [7,10]. Over 60% of the urban population is estimated to be living in the informal settlements [11], that couple with the growing urban economies to attract many people but also increase exposure to climate impacts.

Climate change is adding a new layer to the challenges of urban Africa [12,13•]. Climate change impacts on cities reported widely include extreme climate events, climate-induced flooding, droughts, water stress, heat waves, cold waves to sea level rise, salt water intrusion, coastal erosion and storm surges [14••,15,16••,17]. Vulnerability is unevenly distributed across social groups with informal settlements hit hard. Although most of the coastal zones tend to be occupied by high income populations, the low elevation exposes these areas to salt water intrusion affecting fresh water resources while coastal and beach erosion impacts the transportation infrastructure. These generic climate impacts occur on the backdrop of dynamics associated with sea surface temperature increase in Indian, Pacific and Atlantic oceans [15]. In this paper we synthesize the possible impacts under a 1.5-degree increase in temperature defined as above pre-industrial levels in the Paris Agreement 2015. The paper identifies

possible adaptation and mitigation integration in African cities for resilience building [18]. We use a systematic review of available literature, to present different scenarios for adaptation and mitigation of selected cities.

Framing the scenarios under 1.5 degrees

African cities are catching up on mitigation with micro to city-regional scale interventions [19••,20]. Since the IPCC AR3, adaptation remained high on the agenda of developing countries. Adaptation and mitigation were conceptualized differently and so were the countries' responsibilities, with developed countries concentrating on mitigation, while developing countries focused on adaptation. The AR5 noted the increasing extreme events and impacts of climate change across the globe leading to rethinking the divide between adaptation and mitigation [21]. For example cities in Europe have experienced extreme winters and spring rain causing snowstorms and extensive flooding [22]. These events have led to cities in Europe to develop adaptation plans, demonstrating that adaptation is for both cities in developing and developed countries [23,24•]. Literature has emerged to show the linkages between adaptation and mitigation. However, the means through which adaptation measures can mitigate climate change on one hand and how co-benefits of mitigation measures can increase resilience, remains a grey area [24•,25]. Despite the increase of literature on climate change adaptation and mitigation [7,8,26–29], a knowledge gap exists on how African cities can address the impacts of 1.5 degrees warming and mitigate climate change. With the commitment in the UNFCCC's Paris Agreement to 'limit the temperature increase to 1.5 °C above pre-industrial levels', we use an analytical framework that integrates vulnerability and mitigation to analyse three perspectives for integrating adaptation and mitigation of climate change. The first perspective is that of either adaptation or mitigation, which has been discussed in the preceding argument about the historical developments of IPCC reports. In this perspective it was either adaptation or mitigation perceived on basis of impacts of climate change and where they were anticipated to occur. The second is a combination of *adaptation and mitigation*. This perspective considers that cities need to take into consideration both adaptation and mitigation. In the context of Africa, the longstanding thinking that adaptation is needed over mitigation is changing [30•]. Even when these cities are low emitting, a future development gives a basis for implementing emission avoidance activities while harnessing the co-benefits for resilience. It is also argued that mitigating now will increase adaptation and resilience in the future [31]. The third perspective is that of synergy between adaptation and mitigation under which the issues of reinforcement or constraining of adaptation and mitigation actions on each other becomes important. This perspective is differentiated from the second perspective by how mitigation for example may accentuate vulnerability and make it hard for adaptation and likewise how adaptation measures may increase greenhouse gases and make mitigation futile. There are synergies and tough choices to adapt to impacts of 1.5 degrees and make African cities resilient. These are explored in the conceptual framework in Figure 1 adapted from Solecki *et al.* [32••]. These tough choices include trade offs between reducing vulnerability and mitigation for building safe resilient and inclusive cities [33,34•,35••]. This framing helps to understand the combined adaptation and mitigation pathways under 1.5 degrees warming for African cities. In this paper we recognize different types of cities based on ecological, socio-economic and geographical characteristics. A number of cities were selected for systematic review that included coastal cities, mountainous cities, inland cities, semi-arid and arid cities and desert cities in order to highlight spatially differentiated impacts and under 1.5 °C global warming. These different cities will have different ways of adaptation and mitigation, influenced by development, the demographics and economic opportunities.

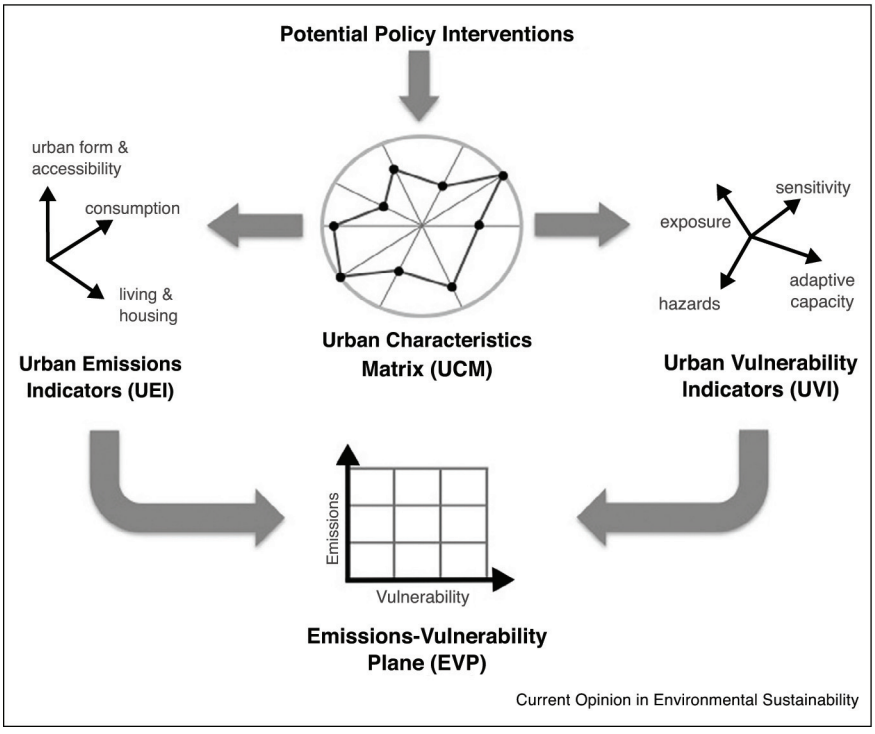
A brief on approach to the review

This paper employed a systematic review selecting literature sources that cover issues under 1.5 degree warming, urban Africa as well as mitigation and adaptation. The review focuses on work published after the Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC AR5), and uses both peer-reviewed and grey literature [36]. Grey literature is included because several of the action plans on climate change in cities do not feature in peer-reviewed literature, yet there are some published policy documents on urban Africa. These documents include Nationally Determined Contributions (NDC's), Nationally Appropriate Mitigation Actions (NAMA's) and Climate Action Plans [37]. Evidence was sought from the literature about the climate impacts reported about selected cities as well as adaptation and mitigation plans. The first step in the systematic review was to search electronic databases for peer-reviewed literature. Inclusion and exclusion criteria were formulated to guide the search of literature. The inclusion key terms were '*climate change*' AND '*temperature rise*' OR '*adaptation*' AND '*mitigation*.' The exclusion criterion was the cut off year of 2015 and a total of 26 literatures sources selected for review. In addition, a total of 10 grey literature documents all of which are National Communications and NDC's were also reviewed. These sources provided sources of information on risk assessment, adaptation, mitigation as well as progress on implementation in the respective cities.

Current reported warming levels and impacts

The highly varied climates of Africa present a complex and uncertain picture about the exact impacts of climate change as well as future possible impacts [12,13•]. In spite of this, there is strong evidence showing that human-induced climate change is affecting the key sectors on the African continent and threatening the gains of decades of development [8,29,38,39•]. Documented evidence for some of African cities show that many are already grappling with a gamut of impacts largely attributed to increasing extreme climate events. It is projected that the impacts will be

Figure 1



Schematic of the Urbanization-Climate Change for mitigation and vulnerability linkages.
Source: Adopted from Solecki *et al*., 2015 (will request for permission to use this figure).

amplified in terms of incidence and intensity with increased warming [14••,40,12]. Sea level rise resulting in coastal erosion and salt-water intrusion is a risk to cities in Africa including Mombasa, Lagos, Abidjan, Alexandria. As noted, a sea-level rise of 0.3 m could lead to the submergence of 17% of Dar-e-Salaam, while also rendering large areas uninhabitable or unsuitable for agriculture as a result of inundation [41]. Many cities are reported to experience extreme temperature leading to droughts as well as associated secondary impacts on water resources and health [42]. For the inland mountainous cities, Addis Ababa is experiencing two extremes of rainfall and droughts which have amplified hazards like floods, poor sanitation, disease outbreaks and food insecurity [33,43]. This has adversely impacted human health and sanitation especially for the urban poor in addition to the disruption of critical urban infrastructure. Similarly, Nairobi is also experiencing the impacts of climate change through increasing temperatures, drought and water resources with reported 2 °C warmer than surrounding areas.

The extensive urban belt along the West African coast is especially vulnerable to the impacts of climate change. This belt accounts for 85% of the West African region's population but it also the zone in which 93% of the region's economic activity is located. Aside from Abuja in Nigeria and Yamoussoukro in Cote D'Ivoire, 13 of the major regional cities are precariously located along the coast. The poorest communities in cities like Dakar, Banjul, Bissau, Freetown, Monrovia, Accra, Kumasi, Lome, Conakry, Abidjan, Cotonou, Lagos and Port Harcourt are already being pushed to the margins along riverbanks and low-lying areas where they are exposed to storm surges, sea-level rise and flooding [50]. Cities like Accra and Kumasi have for long been particularly severely affected, these perturbations resulting in forced dislocation of people. Cities like Cape Town and Johannesburg are experiencing water shortages arising from prolonged droughts which places considerable strain on water supplies [17,44]. Other extreme climate change-related events include floods, windstorms, wild fires and severe storm surges. Perhaps more importantly, like other coastal cities, the Cape Town, Durban are affected by rising sea levels predicted at between 0.3 and 0.6 [45]. The social and economic ramifications of climate change are becoming more evident in Johannesburg with rising temperatures, heavier rainfall and flooding and prolonged dry spells. In North Africa, coastal cities like Casablanca, Tunis and Alexandria have had to cope with extreme episodic weather events characterised by coastal erosion, water scarcity and storm surges that have culminated in destructive floods. For all these cities, a 1.5 °C warming would increase the incidence and intensity of risks associated with these climate-related shocks.

Synthesis of likely impacts and responses of 1.5 degrees warming

Review of literature on selected cities shows that perturbations have negatively affected human livelihoods, ecosystems and projections indicate that a 1.5 °C could double these impacts through increased rainfall in cities like Kampala and Addis Ababa, punctuated by episodes of drought [46]. Elsewhere in the coastal cities in West Africa, further warming could culminate in significant sea level rise of up to 0.5 m leading to severe impacts. For example, cities like Accra and Banjul could especially be severely affected further by inundation. Similar effects would be felt by cities like Cape Town, Durban and Maputo in Southern Africa. Further inland, the current impacts of rising temperatures would inevitably accelerate social conflict and lead to intensification of other economic and environmental challenges. There are various interventions in the different cities given contextual peculiarities in localities across Africa. Scientific knowledge has informed decisions to develop climate action plans leading to planning and implementation of climate change. Important is the growing awareness among decision-makers, professionals and academia about the realities of climate change in enabling political support for essential policy and mobilisation of resources for climate change. African countries (52 out of 54) submitted their NDCs to United Nations Framework — Convention on Climate Change (UNFCC) in 2015, indicating a step in addressing climate change.

However, there exist significant barriers to the climate change adaptation and mitigation responses of African countries. These include inadequate urban-specific climate change, competition with national interests for meagre funds and capacity of urban authorities to mobilize funds to implement climate actions. A case in point is Ethiopia's plans to reduce emissions by 64% conditional to access to international financial support (Nordic Council of Ministers, 2017). Such national level challenges cascade down to city specific planning and implementation. Intermunicipal collaboration and inter-jurisdictional coordination challenges also exist amongst urban authorities across African cities limiting knowledge exchange [47]. Policy coherence is also lacking in Africa's urban sector [11,48,49]. The multiplicity of sub-sectors and actors has created a challenging environment for effectively integrating and mainstreaming key policies to reflect national and international commitments. NDCs presented by many African countries in 2015 list the wide range of sub-sectors ranging from energy, science technology and innovation, finance, environment and natural resources, water, agriculture, forestry among others for the climate change mitigation and adaptation actions. The collective approaches proposed by the different countries fall into four broad areas; energy, Integrated Water Resources Management (IWRM), land use planning and management, and waste pollution management. However, there are marked differences as to where emphasis will be placed in these four key areas in the different cities. For example, Djibouti and Guinea Bissau plan to focus more on promotion of renewable energy options, while Nigeria and Uganda plan to focus more on promoting sustainable use of biomass, waste to energy development, energy efficiency approaches (Djibouti NDCs, 2015; Guinea Bissau NDCs, 2015; Nigeria NDCs, 2015; Uganda NDCs, 2015). There is no evidence to show that these countries have coherently set policy and institutional frameworks as precursors to efficient delivery and cost effectiveness for urban targeted adaptation and mitigation [35••].

Scenarios for 1.5 degree impacts and response in African cities

There are several possible scenarios given the commitments in NDC's under which cities will adapt and or mitigate climate change in Africa. African cities and human settlements are catching up in terms of consumption, resource use and innovation [8]. With current trend and path dependencies in Africa, the combination of reducing vulnerability with mitigation is important [30•]. Given the possible future trends of urban development, one scenario of future African cities under 1.5 degrees warming will be differentiated responses of mitigation and adaptation without systematic and city-wide implementation of adaptation and mitigation. This will most likely be a response to development financing that will switch development aid to climate action. The yet to be built or existing secondary cities in Africa will most likely follow the historical paths also known as the lock-in effect [53]. The second scenario relates with combined adaptation and mitigation. Literature also shows that African cities have began to work on efficient infrastructure, waste systems and economies for Sustainable Development Goals (SDG's) [11,33,54,55]. However this inconsistent city development pathway and the desire to leapfrog systematic transition to modernity by many cities in Africa may have counteracting impacts including speeding up the degradation of ecosystems, limiting economic opportunities, accentuating inefficiencies increased emissions and effect on human wellbeing. For example, Addis Ababa has recently completed a light rail system planned for expansion but installing huge thermal power generation plants to sustain the transportation system's energy demands [56,57].

The second scenario is a systematically planned low carbon development to leverage opportunities of green growth [58–60]. This is embedded in the NDC's and some of the city-specific strategic plans for mitigation and adaptation to climate change. The small-scale transition interventions to renewable energy for major urban sectors as the case in Cape Town, Dar es Salam, Kampala, Walvis Bay all at different city size and intensity of activities is taking shape [8,61,62••]. Some of the cities have seized the opportunity to plan strategically on city-scale development that adapts,

mitigates and reduces risk. This scenario resonates with cities including Cape Town and Kigali. The city plans have incorporated minimization of resource use intensity, renewables, transformation of lifestyles, spatial reconfiguration and creation of economic opportunities [63–65]. The enabling conditions for the scenario are the shift of development aid to climate change or climate financing as development aid [51]. But these plans are still at very early stages of implementation.

The third scenario is the systematic but mixed low carbon development strategies those, which will catch up in terms of urban development, infrastructure development, industrial development and creation of jobs and smart cities but on the other hand with enabling and constraining conditions between adaptation and mitigation [52]. Smart cities concept has different connotations with Information Technology, energy smart grids systems, disaster early warning system integration, green jobs and green business processes [66,67]. Although this sounds a plausible strategy, there is little evidence of how smart cities can potentially promote equitable development since smart cities concept tends to concentrate on economics as the main driver of transition to better living environment. The drivers for this scenario lie in policy and political support to pursue more sustainable, inclusive for all categories of people in the cities. Given the 1.5 degree further warming and likely impacts, this scenario promises to reduce climate change impacts.

Conclusion

African cities are diverse by size, ecologies and spatial structures. In a similar vein, the impacts of climate change vary accordingly but the underlying changes in climate at various spatial scales deliver common but differentiated impacts. Given these diverse impacts, the responses are also diverse. The current responses give a picture of likely future responses under 1.5 degree warming. Most responses are focusing on waste and pollution and at micro to meso scales. From the review, it is clear that future responses should actually be systematically developed beyond the climate action plans. Some of the emerging pathways that will need coordinated and systematic planning include; Green urban infrastructure with a range of sociotechnical solutions; Reducing urban risk and curbing losses especially extensive risk and development accumulated risk; Transforming production processes and infrastructure that creates opportunities for all social groups for inclusiveness; Enhanced urban ecosystems and the possible range of ecosystem services. Such adaptation and mitigation strategies should harness opportunities related to scalable resource efficiency, decentralized services and infrastructure, local employment and expanded markets and strategies that eradicate urban poverty.

Conflict of interest statement

Nothing declared.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Lall SV, Henderson JV, Venables AJ: *Africa's Cities*. 2017.

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3. • Bazrkar MH, Zamani N, Eslamian S, Eslamian A, Dehghan Z: **Urbanization and climate change**.. 619–655 *Handbook of Climate Change Adaptation*. Springer; 2015.

This chapter of special interest because it illustrates the dilemmas of existing large metropolises and Africa has some of the global metropolises. The processes that have produced large cities will continue to occur but cycles of lock-in have to be broken to enable low-carbon development strategies. Applying a systems dynamic analysis, the chapter demonstrates that for existing cities, adaptation or mitigation each is neither an option. These have to be combined to contribute to keeping the 1.5 degrees warming.

4. • Adams S, Klobodu EKM: **Capital flows and the distribution of income in sub-Saharan Africa**. *Econ Anal Policy* 2017, **55**:169-178.

The importance of Foreign Direct Investments and remittances from Africans living in the diaspora has created a dynamic around consumerism seen as likely to continue growing. This paper illustrates the inequality associated with FDI and remittances and though there is a correlation, the few people in Africa that have access to remittances are fuelling differentiated patterns of consumption behaviour that are associated with high carbon footprint. This paper illustrates that it is urgent to combine adaptation and mitigation options can influence the consumer behaviour if warming is to be kept at 1.5 degrees.

5. Myers G: **African ideas of the urban**. *SAGE Handb New Urban Stud* 2017:449.

6. Cobbinah PB, Darkwah RM: *African Urbanism: The Geography of Urban Greenery*. Springer; 2016:149-165.

7. •• Frigerio A: **Facing rapid urbanization: a century of East African Urbanism**. *Int Plan Hist Soc Proc* 2016, **17**:67-78.

This paper illustrates how the historical and current urbanization process in East Africa has been influenced by trials and experimentation of planning and design. This approach with what authors call different political aspirations will continue to determine many parts of these cities to development in a way that other cities have developed yet having a characteristic of a mix with indigenous, traditional aspects of urban development. This paper is important because it shows how critical it is to identify the risks, adaptations and also mitigation actions and most of all how design of the cities can enable an interaction of adaptation and mitigation responses.

8. •• Currie PK, Musango JK: **African urbanization: assimilating urban metabolism into sustainability discourse and practice**. *J Ind Ecol* 2016.

This paper is of outstanding importance focusing on African urban metabolism that is profiled and estimated for future trajectories. The resource profiles serve as a baseline from which to begin assessing the current and future resource intensity of these cities. It also provides insights into the cities' relative resource impact, future consumption trends, and potential options for sustainability interventions. The paper shows that African cities will most likely follow the lock-in path and therefore the resource intensity associated with this path needs an interactive interventions of sustainability that will be adaptation and mitigation.

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13. • Serdeczny O, Adams S, Baarsch F, Coumou D, Robinson A, Hare W, Schaeffer M, Perrette M, Reinhardt J: **Climate change impacts in sub-Saharan Africa: from physical changes to their social repercussions**. *Reg Environ Change* 2016:1-16.
The paper is of special interest because it illustrates the significance of climate risk-induced migration and growth of informal settlements that will accentuate impacts. The movement of people into informal settlements may expose them to a variety of risks different but no less serious than those faced in their place of origin, including outbreaks of infectious disease, flash flooding and food price increases. Impacts across sectors are likely to amplify the overall effect but remain little understood. The paper speaks to an approach which is holistic in addressing the impacts of climate change.

14. •• Lissner TK, Fischer EM: **Differential climate impacts for policy-relevant limits to global warming: the case of 1.5 °C and 2 °C**. *Earth Syst Dyn* 2016, **7**:327.
Of outstanding importance the paper shows the challenge of temperature increase to 1.5 and warming within 2 degrees. The paper speaks to a new normal by suggesting a tipping point of 0.5 degrees which the globe has already passed. In relation to this paper, this shows the urgency of mitigation while addressing the impacts of current temperature increase.

15. Sanderson B: *Interactive Comment on "Half a degree Additional warming, Projections, Prognosis and Impacts (HAPPI): Background and Experimental Design" by Daniel Mitchell et al.*. 2016.

16. •• Baudoin M-A, Vogel C, Nortje K, Naik M: **Living with drought in South Africa: lessons learnt from the recent El Niño drought period**. *Int J Disaster Risk Reduction* 2017, **23**:128-137.
Of outstanding importance the paper shows the challenge of temperature increase and impacts of drought in an African urbanised area. The paper speaks to a new normal of locale specific impacts of El Nino effects with severe impacts on food systems but important for urban south Africa, water. The country has seen the worst drought in last 18 months to an extent of water rationing for cities. In relation to this paper, this shows the urgency of adaptation while addressing the impacts of current temperature increase.

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19. •• Creutzig F, Agoston P, Minx JC, Canadell JG, Andrew RM, Le Quéré C, Peters GP, Sharifi A, Yamagata Y, Dhakal S: **Urban infrastructure choices structure climate solutions**. *Nat Clim Change* 2016, **6**:1054-1056.
An outstanding paper for this review which emphasizes the role cities can and should play to keep the temperature increase to 1.5 degrees. The paper recognizes that cities are becoming increasingly important in combatting climate change, but their overall role in global solution pathways remains unclear. The paper suggests urban climate solutions along the use of existing and newly built infrastructures, providing estimates of the mitigation potential. In the context of African urbanization, the future cities are yet to be built and therefore this paper illustrates how mitigation and adaptation can shape the design and planning of the future cities.

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24. • Geneletti D, Zardo L: **Ecosystem-based adaptation in cities: an analysis of European urban climate adaptation plans**. *Land Use Policy* 2016, **50**:38-47.
Special interest because ecological enhancement in cities is yet to be fully appreciated and more especially in adaptation with mitigation potentials. The paper analyses the importance of having baseline data to inform ecosystem0based adaptation as well the co-benefits associated with the adaptation measures. Although the paper is focused on European cities, there is much to pick from it and European cities for African cities that have differing political aspirations of what the city should be. The notion of modern cities that would integrate blue-green-grey infrastructure for wellbeing and economic growth.

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26. Henderson JV, Storeygard A, Deichmann U: **Has climate change driven urbanization in Africa?** *J Dev Econ* 2017, **124**:60-82.

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Of special interest as one of the few papers that's speaks to low emitting cities. Options advanced ate integrative and bridge adaptation options with mitigation. This paper clearly identifies the possible strategies through which African cities can contribute to keeping temperature increase to 1.5 degrees by limiting and or avoiding the infrastructure lock-in.

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32. •• Solecki W, Seto KC, Balk D, Bigio A, Boone CG, Creutzig F, Fragkias M, Lwasa S, Marcotullio P, Romero-Lankao P, Zwickel T: **A conceptual framework for an urban areas typology to integrate climate change mitigation and adaptation**. *Urban Clim* 2015, **14**:116-137 http://dx.doi.org/10.1016/j.uclim.2015.07.001.
Of outstanding importance because it provides a framework for integrating vulnerability assessments with emissions as a first level. The paper also defines the combination of adaptation and mitigation and shows that cities that high emitters should define adaptation interventions while addressing mitigation. The three scenarios presented in this paper are very clearly mapped by this paper.

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34. • Costa H, Floater G, Finnegan J: **Climate-resilient cities**. *Econ Climate-Resilient Dev* 2016:143.
This book illustrates the economic imperatives of adaptation to climate change which will determine how adaptive or mitigative cities will be particularly in Africa. The book is of special interest because it relates the economic costs of not mitigating as well as costs associated with non action towards adaptation. For resilient cities under a new normal of climate regime, the need to factor in economics is more than needed and the scenarios in this paper would be achievable when economics is considered.

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